PATENT SPECIFICATION

(11) 1 301 615

DRAWINGS ATTACHED

(21) Application No. 10153/71 (22) Filed 20 April 1971

(31) Convention Application No. 7 014 874 (32) Filed 23 April 1970 in

(33) France (FR)

(44) Complete Specification Published 4 Jan. 1973

(51) International Classification F02C 7/26

(52) Index at acceptance

F1J 1X 2A1A 3

F1C D2J2H D2J2J3

F1G 18

(19)

1 301 615

(72) Inventor JACQUES EDOUARD LAMY

(54) IMPROVEMENTS IN OR RELATING TO MULTIFLOW GAS TURBINE JET ENGINES, IN PARTICULAR TO IMPROVE STARTING THEREOF

(71) We, SOCIETE NATIONALE D'ETUDE ET DE CONSTRUCTION DE MOTEURS D'AVIATION, a French Body Corporate, of 150 Boulevard Haussmann, 75-Paris, France, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to multiflow gas turbine jet engines, hereinafter called turbojet engines, which are used for aircraft propulsion and comprise a compressor the upstream stage or stages (often referred to as the "fan") of which serves or serve to compress an incident air flow which is subsequently split into at least two concentric flows. In a by-pass jet engine for example, the internal flow is employed for the combustion of a fuel which is injected into a combustion chamber, thus producing hot gases which are first of all expanded across a turbine providing the requisite power for the compression function, and then through a propulsion nozzle, whilst the external flow is used chiefly to dilute the hot gases in the nozzle in order to improve the efficiency of propulsion.

In order to start an engine of this kind, its rotor or rotors is or are rotated by means of a starter. Starting is often made difficult by the fact that the rotation of the fan rotor requires a relatively high power since the fan not only has to compress the central core of the incident air flow, which furnishes the internal flow (the latter being the sole flow fraction which is effective in the starting up of the engine), but also the peripheral portion which constitutes the external flow which is not effective in the starting function. Thus, in order to maintain the weight and size of the starter within reasonable limits, there is a risk that the designer will be forced to limit the external flow, which could hamper the development of multiflow jet engines towards increased by-pass ratios.

It is possible to overcome this drawback by gating the external flow of the peripheral portion of the flow passing through the fan. Already, a variety of methods for effecting this kind of gating have been proposed, for example using flaps or variable-pitch blading, or even pneumatic restriction. These known methods have been directed chiefly towards varying the external flow rate in order in particular to regulate the by-pass ratio.

The invention is concerned essentially with facilitating start-up.

In accordance with the invention, there is provided a multiflow turbojet engine comprising an axial flow fan, which is used to compress an incident air flow in order to produce a compressed air flow which is split by an annular wall into an internal flow designed to supply a combustion chamber and an external flow coaxial to the internal one; and a device designed to facilitate starting of the turbojet engine and comprising a ring of blades which, at the most, have substantially the radial height of the external flow, these blades being located upstream of the peripheral part of the input blading of the fan rotor and being articulated about pivot axes disposed substantially radially of the axis of the engine, means for inclining said blades by pivoting them about said pivot axes so that the trailing edges of the blades move in the direction of rotation of the fan and means for supplying compressed gas to passages formed in said blades and opening at their trailing edges through bleed orifices.

This combination of features enables the power absorbed by the rotor at start-up to be reduced, this being achieved by simultaneously providing gating and deflecting the peripheral zone of the incident air flow, said deflection being produced by a combination of the inclination of the blades and the injection of air whose tangential component is directed in the direction of rota-

tion of the rotor.

The two faces of each blade will preferably be symmetrical relative to the axial plane of the blade: in the following the term "deflex" will be used to describe a ring of symmetrical blades of this kind. During normal operation of the jet engine, the supply of compressed air is cut off and the blades of the deflex are feathered or located in radial planes passing through the engine axis so that the deflex has no gating effect or deflecting effect upon the incident air flow. In the starting position, the reduction in power taken by the fan is due on the one hand to the gating effect exerted by the deflex on the incident air flow and on the other hand to the deflection of the incident air flow in the direction of rotation of the rotor, which deflection is produced by inclining the blades of the deflex and is supplemented by blowing air through the trailing edges of the blades. Thus, apart from the reduction in rotor load produced by this deflection, which results from the reduction of the incidence of the air over the blades of its first stage, up to the point of striking the blade upper surface, the air blown through the trailing edges can also strike the blade upper surface, at least at the beginning of the start-up phase, thus aiding initial rotation of the rotor. The "blown" deflex can thus reduce the starting torque substantially more than would be the case if the air bleed facility were not provided.

The said deflection of the incident air, produced by the combination of means in accordance with the invention, also makes it possible to facilitate re-starting of a jet engine after flame-out in flight, this by increasing the angle of incidence, relative to the rear of the blades of the first stage of the fan (now acting as a turbine), of the air flow created by the forward motion of the aircraft. In order to restart the engine in flight, the blades of the deflex are thus set in the same manner as for ground starting and are supplied with compressed air so that the torque fraction produced by the peripheral portion of the fan, acting as a turbine, is increased, thus increasing the velocity of rotation of the fan and consequently improving the starting conditions.

If, instead of restarting the jet engine after a shut-down in flight, it is desired to limit the wind-milling, the gating effect exerted by the deflex enables the power produced by the fan to be reduced. Obviously then, in this circumstance, it is desirable to increase the gating effect; the blades of the deflex will therefore preferably be adjustable between the gating and zero deflection position, defined hereinbefore and utilised in normal flight, and a maximum gating position in which they are disposed transversely and are more or less contiguous with one another, in the plane perpendicular to the engine axis and containing their pivot axes.

The blowing of air through the trailing edge of each blade can be effected perpendicularly to its pivot axis or in the direction which is inclined towards the nozzle axis. In the latter case, the air in the peripheral zone of the incident flow is deflected towards the central part of the fan which supplies the internal flow. Higher preliminary rotation speeds can be achieved by inclining the bleed orifices at the trailing edges of the blades in relation to the plane of symmetry of these latter and in the direction of rotation of the rotor.

In addition, the blades may have at most substantially the radial height of the external flow. The invention is thus not limited to a ring of blades which strictly occupies the whole of the peripheral region of the incident flow furnishing the external flow fraction. The height of the blades is determined by the particular objective in question, namely that of reducing the power absorbed by the fan whilst supplying the requisite internal air flow for starting the jet engine. Since, as indicated hereinbefore, the gating can be moderated, the blades of the deflex can be shorter than the height of the external flow, use possibly being made of the facility referred to hereinbefore, for deflecting air from the peripheral regions of the incident flow towards the central part of the fan.

The invention will now be further described, by way of example, with reference to the accompanying drawings, in which:—

Figure 1 is a schematic axial half-section of the forward part of the turbojet engine equipped with a "blown" deflex in accordance with the invention;

Figure 2 is a fragmentary view on a larger scale, in the form of a developed cylindrical section, of the deflex and the first stage of the fan of the turbojet engine shown in Figure 1;

Figure 3 is a diagram showing the velocities of the input air to the first stage, at start-up.

Figure 4 is a section through a variant embodiment of deflex blades;

Figure 5 is a partial view similar to that of Figure 1 illustrating on a larger scale the method of controlling the pivotting of the deflex blades;

Figure 6 is a partial elevational view in accordance with the arrow F of Figure 5, with a partial section on the line VI-VI;

Figure 7 is a partial developed view of Figure 5, showing the blades of the deflex and their control arrangement;

Figure 8 is a schematic view illustrating

the control of the supply of compressed air to the deflex blades:

Figure 9 is a view similar to that of Figure 5 illustrating the control of the blades by jacks;

Figure 10 is a sectional view on the line X-X of Figure 9;

Figure 11 is a view similar to that of Figure 10, illustrating another embodiment of a jet control system; and

Figure 12 is a partial view in the direction of arrow F_1 in Figure 11.

Figure 1 illustrates an axial half-section through the front of a dual-flow two-stage turbojet engine, namely one with a low pressure stage and a high pressure stage. The rotor 1 of the low pressure stage is provided at the front with the moving blades 3 of a fan 4 and at the rear with a low pressure turbine (not shown). The rotor 2 of the high pressure stage is provided at the front with the moving blades 5 of a high pressure compressor 6 and, at the rear, with a high-pressure turbine (not shown). A turbojet engine of this kind will be well known to those skilled in the art and requires no further description in detail. In operation, the incident air flows through an air intake 7, is compressed by the fan 4 and is split into two coaxial flows. The internal flow is recompressed by the compressor 6 and then passes to the combustion chamber (not shown), where it brings about the combustion of a fuel in order to form hot gases which expand first of all across the high pressure turbine and the low pressure turbine, then through a nozzle (not shown) to form a propulsive jet. The external flow passes through an annular duct 8 which opens into the nozzle. The said external flow is used principally, in a conventional manner, to cool the nacelle and nozzle and to dilute the hot gases in the latter. It will be observed that the different stages of the fan 4 comprise a row of stator vanes 9, with the exception of the first stage whose moving blading 3a is supplied directly with the air coming from the intake 7.

In accordance with the invention, the fixed part 10 of the jet engine is equipped, between the moving blading 3a of the first stage of the fan 4 and the air intake 7, with a deflex 11 constituted by a ring of blades 12 having substantially the same radial height as the annular duct 8 and assembled to pivot about radial axes 13 uniformly distributed around the circumference of the fixed section 10. As Figures 2 and 5 show more clearly, each blade 12 has a symmetrical external profile in relation to a plane 14 passing through its pivot axis 13; each blade is hollow and its internal cavity 15 communicates with the exterior through a series of orifices 16 opening at the trailing edge 16. The external tip of each blade 12 is provided with a threaded sleeve 18 which is articulated about its axis 13 in a bearing block 19 on the fixed section 10. The sleeve 18 of each blade 12 opens into the internal cavity 15 and is supplied with compressed air from a manifold 20 fixed to the section 10 through a tube 21 which fits fluid-tightly into the sleeve 18.

As explained hereinafter in greater detail, in the context of Figures 5 and 8, a control device, comprising links 23 and a mobile ring 24, enables all the blades 12 of the deflex 11 to be pivoted, and means are provided for supplying the manifold 20 with compressed air when it is desired to start the jet engine.

During normal operation of the engine, the blades 12 are located in radial planes, that is to say that their planes of symmetry 14 intersect at the axis 25 of the engine, this position being shown in particular in Figures 1 and 5. The blades 12 thus produce no deflection of the air arriving through the intake 7 so that this air arrives parallel to the axis 25 on the first blade ring 3a of the fan. The blades 3b of said blading 3a are supplied at a relative velocity $\overrightarrow{W1}$ which is the resultant of the velocity $\overrightarrow{V1}$ of the incident air and of $-\vec{u}$, $\vec{u}$ being the whirl velocity of the blading 3a; said velocity $\overrightarrow{W1}$, which has a small angle of incidence at start-up, is illustrated in broken line in the velocity diagram of Figure 3. During start-up of the jet-engine, the velocities $\overrightarrow{V1}$ and $\vec{u}$ are low. The blades 12 of the deflex 11 are inclined about their axes 13 in the direction of motion of the first blading 3a of the fan (Figure 2) so that the blades 12 deflect the incident air, giving it a velocity $\overrightarrow{V2}$ which has a tangential component $\overrightarrow{\Delta W_{1u}}$, and so that the blading 3a has an incident relative velocity of $\overrightarrow{W'1}$ (Figure 3). The blading 3a, having the incident relative velocity $\overrightarrow{W'1}$ at a negative angle of incidence which is smaller (but larger in terms of absolute value) than that of $\overrightarrow{W1}$, will produce a lower flow; in other words, the inclination of the blades of the deflex 11 produces a gating effect. The air blown through the trailing edge 17 of the blades 17, produced by the compressed air supply and exiting from the orifices 16, supplements this gating effect:

—on the one hand because the deflection produced by the blown air is added to the deflection of tangential component $\overrightarrow{\Delta W'_{1u}}$ produced by the inclination of the blades 12, thus giving rise to a total deflection of tangential component $\overrightarrow{\Delta W''_{1u}}$, so that the first blading 3*a* has an incident relative velocity $\overrightarrow{W''_{1u}}$ whose angle of incidence is still more negative, thus increasing the gating effect;

—on the other hand because said blown air acts upon the upper surface or rear face, of the blades 3*b* and thus assists their rotation, partially lightening the load on the starter.

In Figures 1 and 5, the air bleed orifices 16 in each blade 12 are directed perpendicularly to its pivot axis 13. The arrangement of Figure 4, however, can be used as a variant embodiment, the deflex 11 here being constituted by blades 12*a* whose air bleed orifices 16*a* are inclined towards the axis 25 of the nozzle. The compressed air blown through these orifices 16*a* deflects the incident air towards the central part of the fan 4, thus supplying the internal flow.

Figures 5 to 7 illustrate an embodiment of the control system used for the ring 24 which actuates the blades of the deflex through the links 23, the latter being secured non-rotationally to the pivots 18 by the hollow screws 22. Each of these links 23 is fixed to a blade 12 at 45° to its plane of symmetry 14 and is articulated to the ring 24 through a pivot 23*a*. The ring 24 is movable rotationally and translationally about the fixed section 10 of the jet engine, so that it can rotate all the blades 12 simultaneously between the position shown in broken line in Figure 7 (position of Figures 1 and 5) and the position shown in full line (which is the starting position of Figure 2). In order to enable this movement to take place, each link 23 must be capable of slight torsional movement, since the axes of the pivots 23*a* are not parallel with the axes 13 of the blades except in the position shown in solid line. To this end, the links 23 are cut from plates of flexible material and perforated in the manner shown in Figure 7.

The U-shaped bracket 26 carries a mechanism 27 which controls the ring 24. Said mechanism 27 comprises two elements located in diametrally opposite regions of the air intake, only one of which, 27*a*, has actually been shown in Figures 5 and 6. Each of these elements is coupled through a link 28 to a plate 29 fixed to the ring 24. Said link 28 is articulated at 28*a* to the plate 29 and, at its other end 28*b*, to a toothed sector 30 pivotally assembled at 30*a* on the frame of the mechanism 27*a*. The sector 30 meshes with a transverse endless screw 31 having keyed to its shaft a gear 32 which itself meshes with a small worm screw 33 operated by an electric motor (not shown). If the electric motors of the two elements 27*a* of the mechanism 27 are rotated simultaneously in the appropriate direction, the gearing arrangements described will simultaneously cause the two toothed sectors 30 to rotate and these in turn will rotate the ring 24 through the medium of the links 28. Because said ring 24 is connected to the blades 12 by the links 23, the rotation of the ring 24 is accompanied by translatory motion which pivots the blades 12 between the position shown in broken-line and the full-line position. The links 28 must, of course, follow the movement of the ring 24 and, to this end, the joints 28*a* and 28*b* are of the knuckle or universal type.

Figure 8 schematically illustrates how the blowing of air from the blades to the deflex may be controlled by means of a needle valve 34 operated by one of the elements 27*a* of the mechanism 17. The valve 34 is connected through an input line 35 to the compressed air source, for example the delivery side of the compressor 6, and through an output line 36 to the manifold 20. The valve comprises a needle obturator 37 the stem 37*a* of which is connected to a piston 38 which can slide in sealed manner within a bore 39 in the body of the valve 34. The rod 38*a* of said piston can slide in the guide 40 attached to a fixed section 10 of the jet engine, such as the body of the valve 34, and carries a rack 41 which meshes with a gear 42 attached to the free end of the worm screw 31 of the mechanism element 27*a*. An electric motor driving said mechanism element is shown schematically at 33*a*. The mechanism is adjusted so that in normal flight, that is to say when the blades 12 are in the position shown in Figures 1 and 5 and illustrated in broken-line in Figure 7, the needle 37 completely shuts off communication between the input 35 and the output 36. When the motors 33*a* are started to move the system into the engine starting position, the gear 42 drives a rod 41, the piston 38 and the needle 37 in such a manner as to open the valve and, when the blades 12 are in the starting position shown in Figure 2 and illustrated in solid line in Figure 7, the valve will be fully open. The manifold 20 is thus progressively supplied with compressed air, making it possible to adjust, at the same time as the position of the blades 12, the air flow through the openings 16.

The control device described above in respect of Figures 5 to 8 has been successfully used in ground tests. Figures 9 and

10 illustrate a control device of smaller radial extent, which can be used in an aircraft in flight. In this control device, the links 28 are still respectively articulated to the two diametrically opposite plates 29 of the ring 24. Each link 28 is articulated by a knuckle joint 28c to the end of an arm 43a of a bellcrank lever 43 pivoting on a bracket 44 attached to the fixed section 10 of the jet engine, the other arm 43b of which lever is articulated to the end of the rod 45a of a jack 45 whose cylinder is pivotally mounted on a bracket 46 likewise attached to the fixed section 10. The bellcrank lever 43 and the jack 45 operate transversely of the engine axis: Figure 9 shows how the arm 43b is offset in relation to the arm 43a and that the latter is inclined towards the front of the engine so that the brackets 44 and 46 can readily be attached behind the ring 24. The control of the ring 24 is thus effected by two diametrally opposite jacks 45 at the periphery of the engine; these jacks are of the double-acting type, and a valve which has not been shown enables the aircraft pilot to control the extension of the jacks and consequently the position of the ring 24 and the blades 12.

If it is preferred to arrange the jacks parallel to the axis of the engine, then the arrangement of Figures 11 and 12 can be employed, in which each link 28 is articulated through a knuckle joint 28b to the end of an arm 47a of a bellcrank lever 47 pivoting about a radial axis 48 in a bracket 49 attached to the fixed section 10 of the engine, the other arm 47b of said bellcrank lever being articulated to the end of the rod 50a of a jack 50. The two jacks 50 are articulated to brackets (not shown) attached to diametrally opposite regions of the fixed section 10 of the engine. Here, again, a valve which is not shown enables the pilot to regulate the extension of the two jacks and consequently to adjust the ring 24 and the blades 12.

In these two latter embodiments, the supply of compressed air to the manifold 20 can be effected by any convenient means, for example through a valve which may or may not be slaved to the position of the blades 12. Preferably these latter will be designed to pivot not only between the normal flight position shown in broken line in Figure 7 and the start-up position shown in solid line, but also into the position shown in chain-dot line where they are practically contiguous with one another and close off virtually the whole of the peripheral zone of the fan 4. As already explained, this arrangement makes it possible to limit windmilling of the rotor after the engine has been shut down in flight.

The advantages of the blown deflex in accordance with the invention are not limited to those already mentioned, namely easier ground starting and in flight restarting. It is possible to pivot the blades 12 in order to reduce the fan noise, for example when the aircraft is in the approach figuration, reducing the relative speed of incidence at the periphery of the first blade ring 3a of the fan 4. The noise-reducing effect will be particularly marked in the case of a fan having a high peripheral velocity.

Moreover, the blades 12a can act as variable-pitch blading in advance of the fan 4, this having the known advantage of making it possible to vary the relative balance of the speeds of rotation of the two stages 1 and 2 in such a way as to favour thrust or specific fuel consumption. This also constitutes an effective remedy against vibration (rotary stall or flutter).

WHAT WE CLAIM IS:—

1. A multiflow turbojet engine comprising an axial flow fan, which is used to compress an incident air flow in order to produce a compressed air flow which is split by an annular wall into an internal flow designed to supply a combustion chamber and an external flow coaxial to the internal one, and a device designed to facilitate starting of the turbojet engine and comprising a ring of blades which, at the most, have substantially the radial height of the external flow, these blades being located upstream of the peripheral part of the input blading of the fan rotor and being articulated about pivot axes disposed substantially radially of the axis of the engine, means for inclining said blades by pivoting them about said pivot axes so that the trailing edges of the blades move in the direction of rotation of the fan and means for supplying compressed gas to passages formed in said blades and opening at their trailing edges through bleed orifices.

2. A turbojet engine as claimed in claim 1, wherein the bleed orifices are inclined towards the axis of the turbojet engine and/or in the direction of rotation of the rotor.

3. A turbojet engine as claimed in claim 1 or claim 2, wherein each blade has a profile which is symmetrical relative to a plane passing through its pivot axis and wherein means are provided for arranging said blades, in the inoperative condition, in radial planes passing through the axis of the turbojet engine.

4. A turbojet engine as claimed in any one of the preceding claims, wherein means are provided for pivoting the blades into a position in which they are located in a transverse plane in relation to the axis of the turbojet engine.

5. A turbojet engine as claimed in any one of the preceding claims, wherein the

pivoting of the blades is controlled by links fixed to the blades and articulated to a ring which is movable rotationally and translationally about the turbojet engine and wherein the links are articulated to the ring about pivot axes disposed substantially radially and are sufficiently flexible in order to undergo slight twisting during the movement of said ring.

6. A turbojet engine as claimed in any one of the preceding claims, wherein pivoting of the blades and supply of compressed gas to them are controlled in combination so that the air bleed takes place exclusively when the blades are inclined in the direction of rotation of the rotor.

7. A turbojet engine substantially as hereinbefore described with reference to the accompanying drawings.

ARTHUR R. DAVIES,
Chartered Patent Agents,
27, Imperial Square,
Cheltenham,
and
115, High Holborn,
London, W.C.1.
Agents for the Applicants.

Printed for Her Majesty's Stationery Office by The Tweeddale Press Ltd., Berwick-upon-Tweed, 1972.
Published at the Patent Office, 25 Southampton Buildings, London WC2A 1AY from which copies may be obtained.

1,301,615 COMPLETE SPECIFICATION
6 SHEETS This drawing is a reproduction of the Original on a reduced scale.
SHEET 1

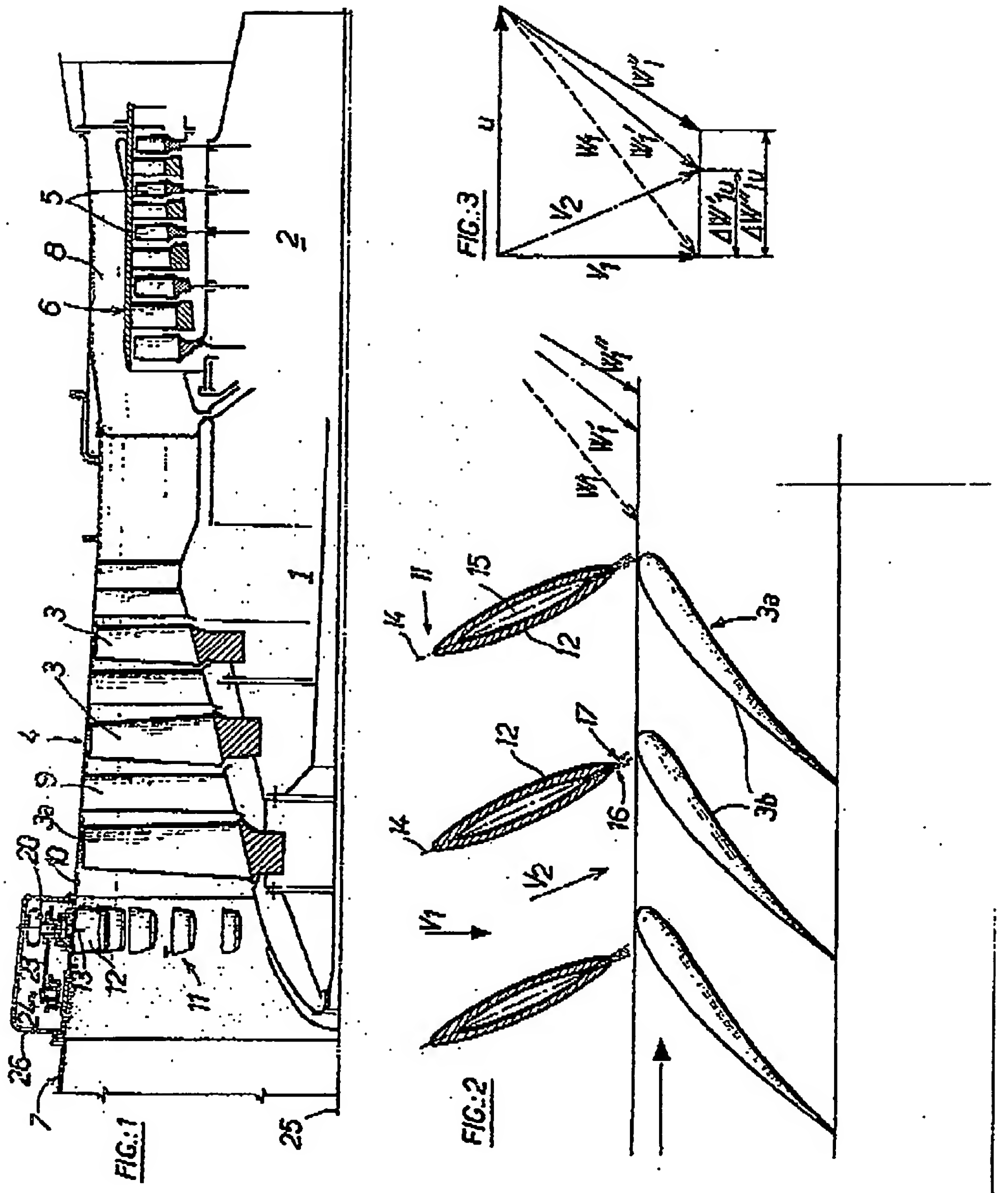


FIG.1

FIG.2

FIG.3

1,301,615 COMPLETE SPECIFICATION
6 SHEETS *This drawing is a reproduction of the Original on a reduced scale.*
SHEET 2

FIG.:5 FIG.:4

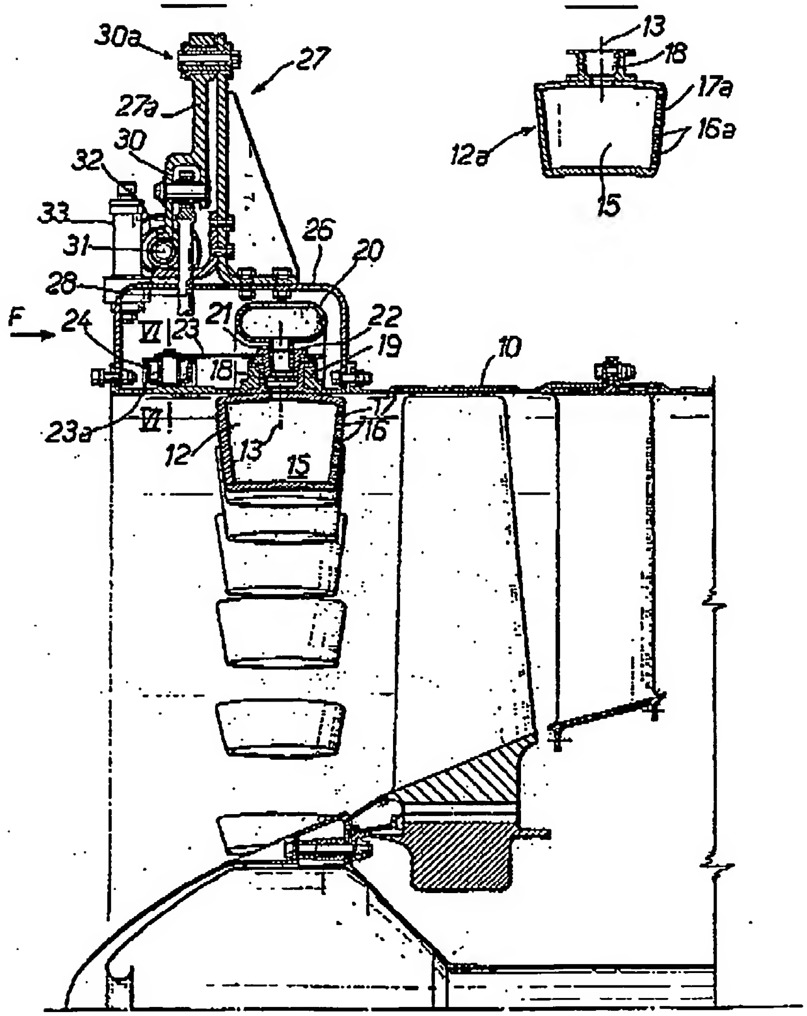


FIG.:6

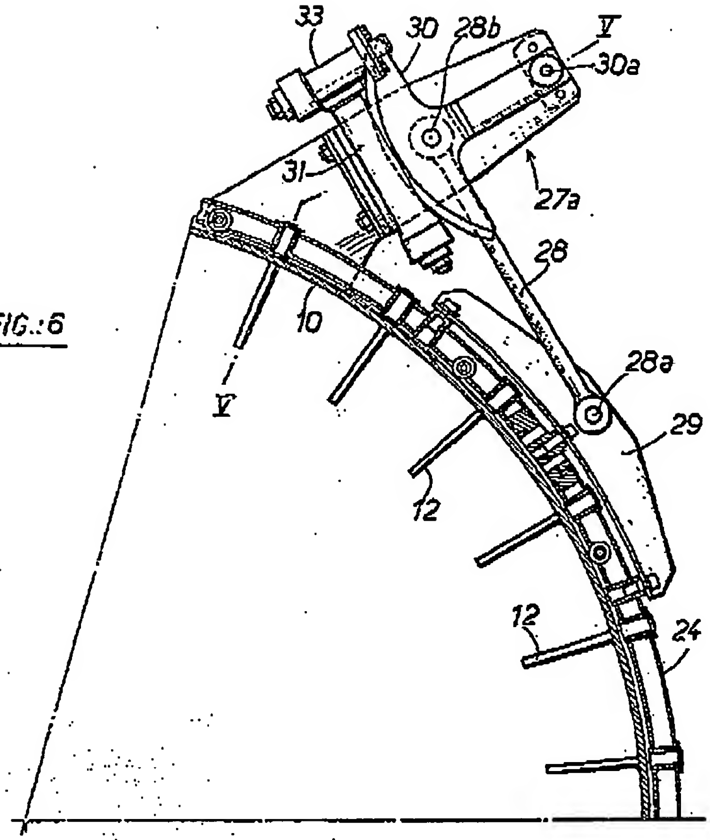
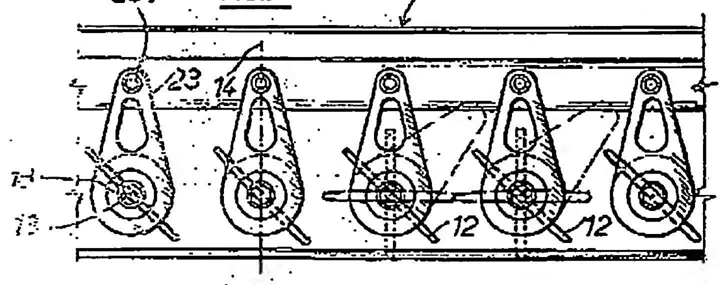


FIG.:7



1,301,615 COMPLETE SPECIFICATION
6 SHEETS This drawing is a reproduction of the Original on a reduced scale.
SHEET 4

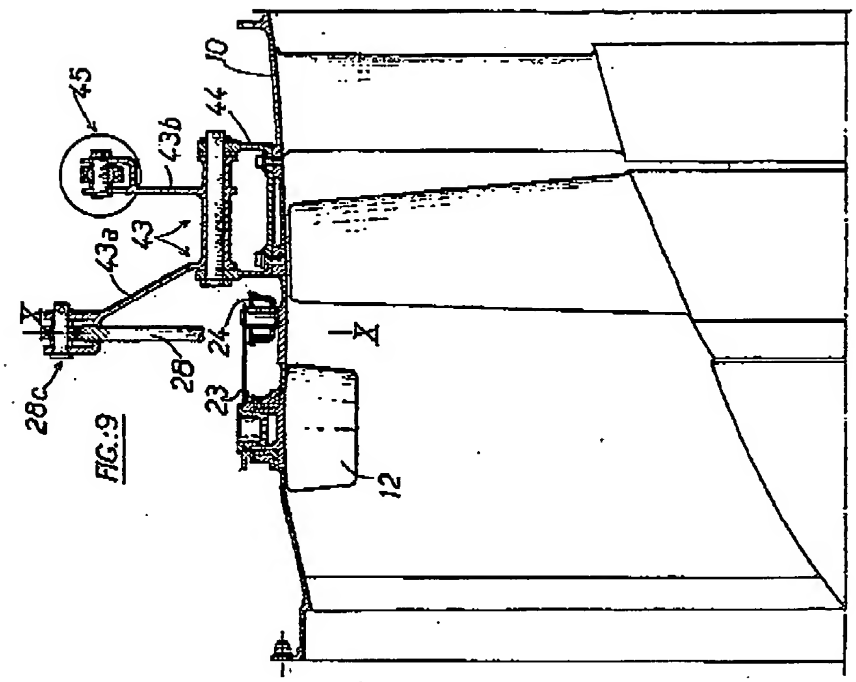


FIG.9

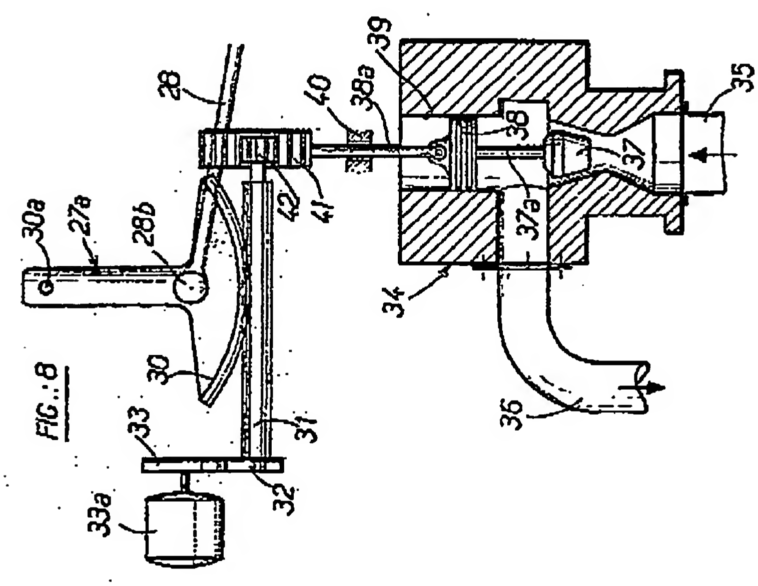


FIG..8

1,301,615 COMPLETE SPECIFICATION
6 SHEETS This drawing is a reproduction of the Original on a reduced scale.
SHEET 5

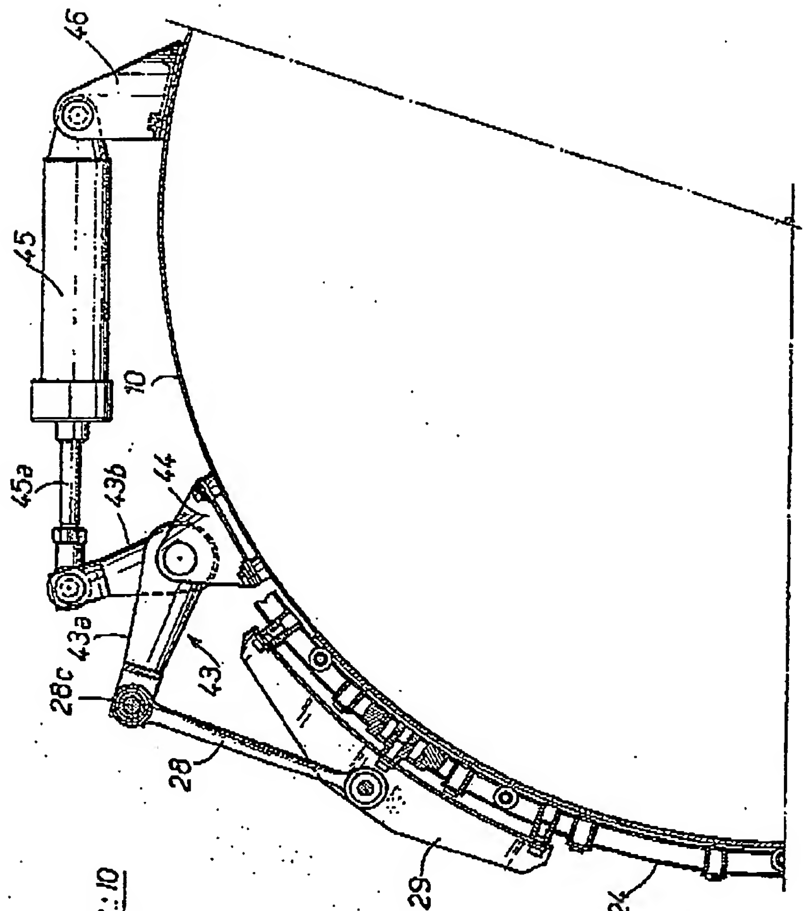


FIG: 10

1,301,615 COMPLETE SPECIFICATION
6 SHEETS This drawing is a reproduction of the Original on a reduced scale.
SHEET 6

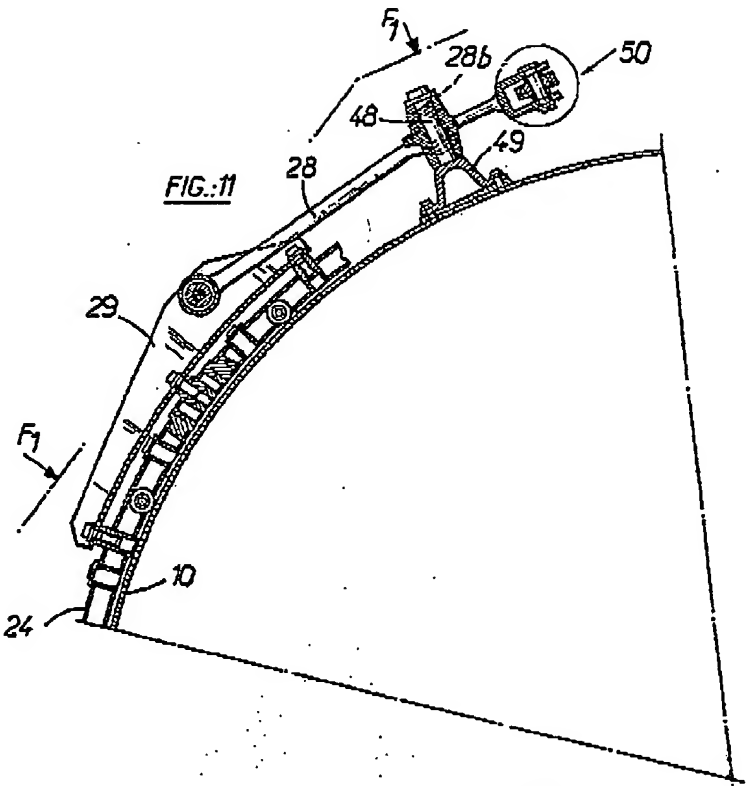


FIG.:11

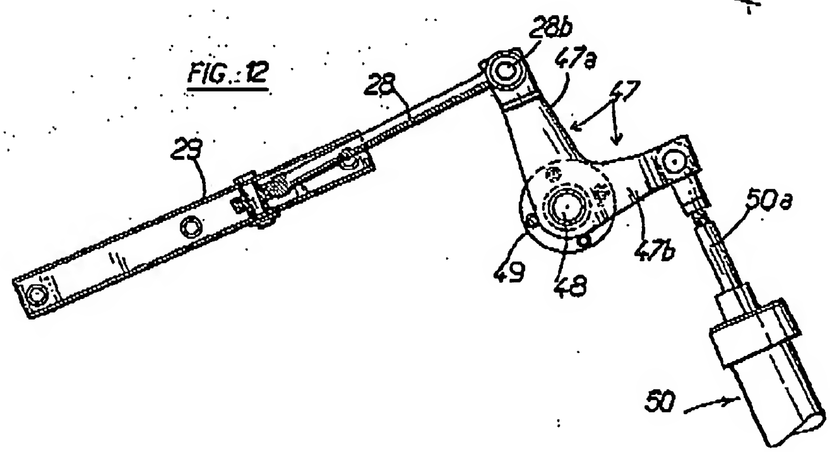


FIG.:12